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(54) **VACUUM INSULATED REFRIGERATOR STRUCTURE WITH FEATURE FOR CONTROLLING DEFORMATION AND IMPROVED AIR WITHDRAWAL**

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F25D 23/06 (2006.01)

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(52) **U.S. Cl.**
CPC **F16L 59/065** (2013.01); **F25D 23/062** (2013.01); **F25D 23/063** (2013.01);
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CPC **F25D 23/062**; **F25D 23/065**; **F25D 23/066**;
F25D 23/063; **F25D 23/085**; **F25D 2201/126**; **F25D 2201/14**; **F16L 59/065**
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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,536,990 A 8/1985 Siegrist et al.
6,230,500 B1 5/2001 Mao et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 103968196 B 10/2017
EP 1335171 A1 8/2003
(Continued)

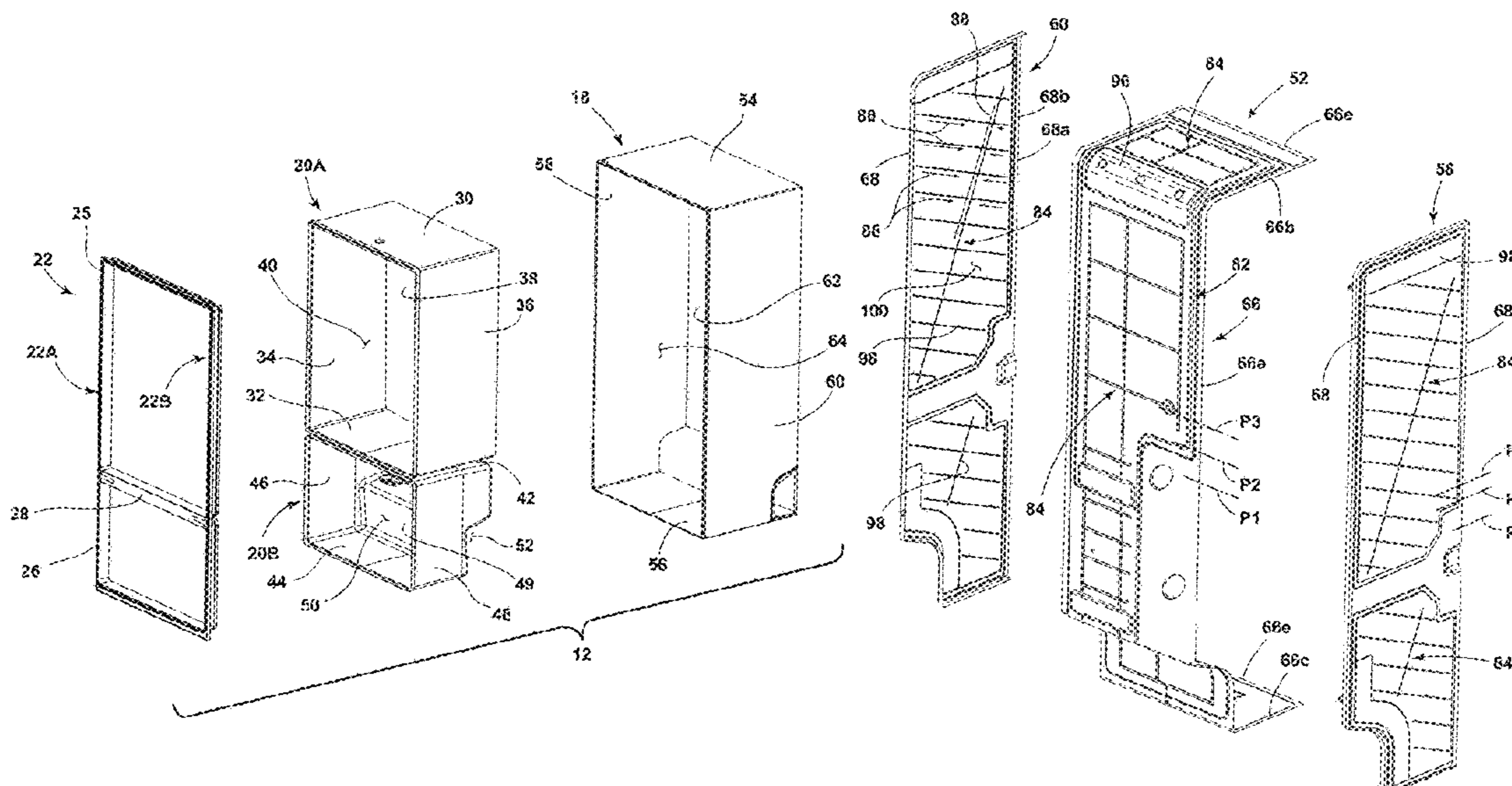
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(57) **ABSTRACT**

A vacuum insulated structure including a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and first rib formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion, a second cover member, and thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first rib defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process.

19 Claims, 9 Drawing Sheets



(51)	Int. Cl. <i>F25D 23/08</i> (2006.01) <i>F25D 29/00</i> (2006.01)	11,448,355 B2 * 9/2022 Ekshinge F25D 29/00 2007/0227179 A1 10/2007 Yoo et al. 2010/0180627 A1 7/2010 Hanke 2010/0187241 A1 7/2010 Hanke
(52)	U.S. Cl. CPC <i>F25D 23/065</i> (2013.01); <i>F25D 23/066</i> (2013.01); <i>F25D 23/085</i> (2013.01); <i>F25D</i> <i>29/00</i> (2013.01); <i>F25D 2201/126</i> (2013.01); <i>F25D 2201/14</i> (2013.01)	2013/0256319 A1 10/2013 Kuehl et al. 2016/0258671 A1 9/2016 Allard et al. 2017/0190081 A1 7/2017 Naik et al. 2018/0003427 A1 1/2018 Godbole 2018/0238605 A1 8/2018 Kojima et al. 2019/0128594 A1 5/2019 Allard et al. 2019/0137166 A1 5/2019 Dherde et al. 2019/0145697 A1 5/2019 Naik et al. 2019/0257573 A1 8/2019 Kojima et al. 2019/0285336 A1 9/2019 Naik et al. 2020/0103067 A1 * 4/2020 Allard F25D 23/085 2022/0221099 A1 7/2022 Ekshinge et al.
(56)	References Cited U.S. PATENT DOCUMENTS 8,944,541 B2 2/2015 Allard et al. 8,986,483 B2 3/2015 Cur et al. 9,464,751 B2 10/2016 Toshimitsu et al. 9,574,819 B2 2/2017 Kang et al. 10,337,788 B2 7/2019 Jung et al. 10,385,610 B2 8/2019 Artwohl et al. 10,465,974 B2 11/2019 Jung et al. 10,591,199 B2 3/2020 Jung et al. 10,619,912 B2 4/2020 Liu et al. 10,697,696 B1 6/2020 Ekshinge et al. 10,697,698 B2 6/2020 Dherde et al. 10,746,343 B2 8/2020 Allard et al. 10,989,461 B2 4/2021 Dherde et al. 11,029,080 B2 6/2021 Naik et al. 11,035,607 B2 6/2021 Naik et al. 11,247,369 B2 2/2022 Naik et al. 11,313,610 B2 4/2022 Godbole	FOREIGN PATENT DOCUMENTS EP 3628947 A1 * 4/2020 F16L 59/065 GB 730146 5/1955 GB 760338 10/1956 JP 4580843 11/2010 JP 2013088036 A 5/2013 JP 5689387 B2 3/2015 KR 100541061 B1 1/2006 KR 20190092602 A 8/2019 TW I494530 B 8/2015 WO 2020158012 A1 8/2020

* cited by examiner

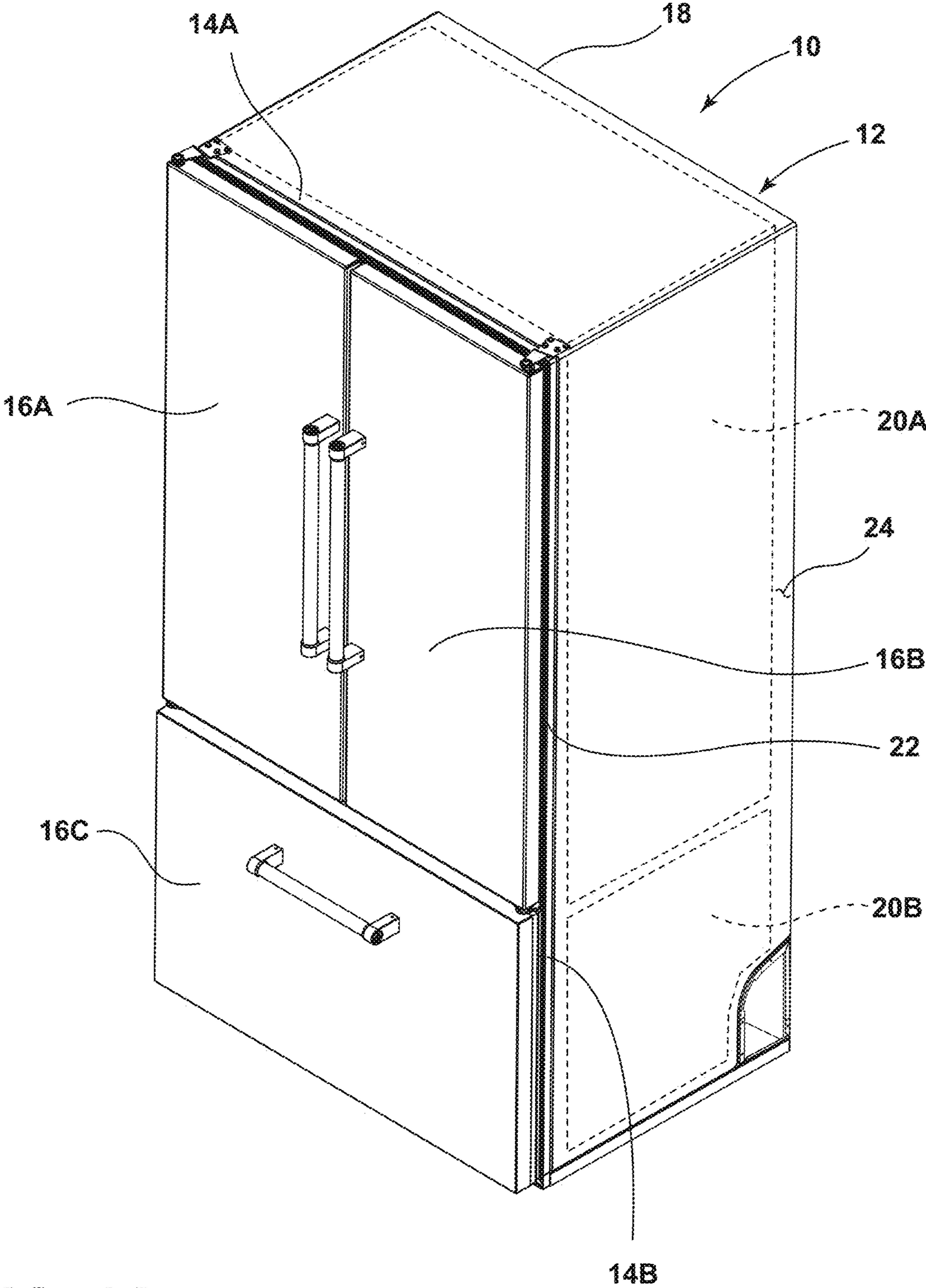


FIG. 1A

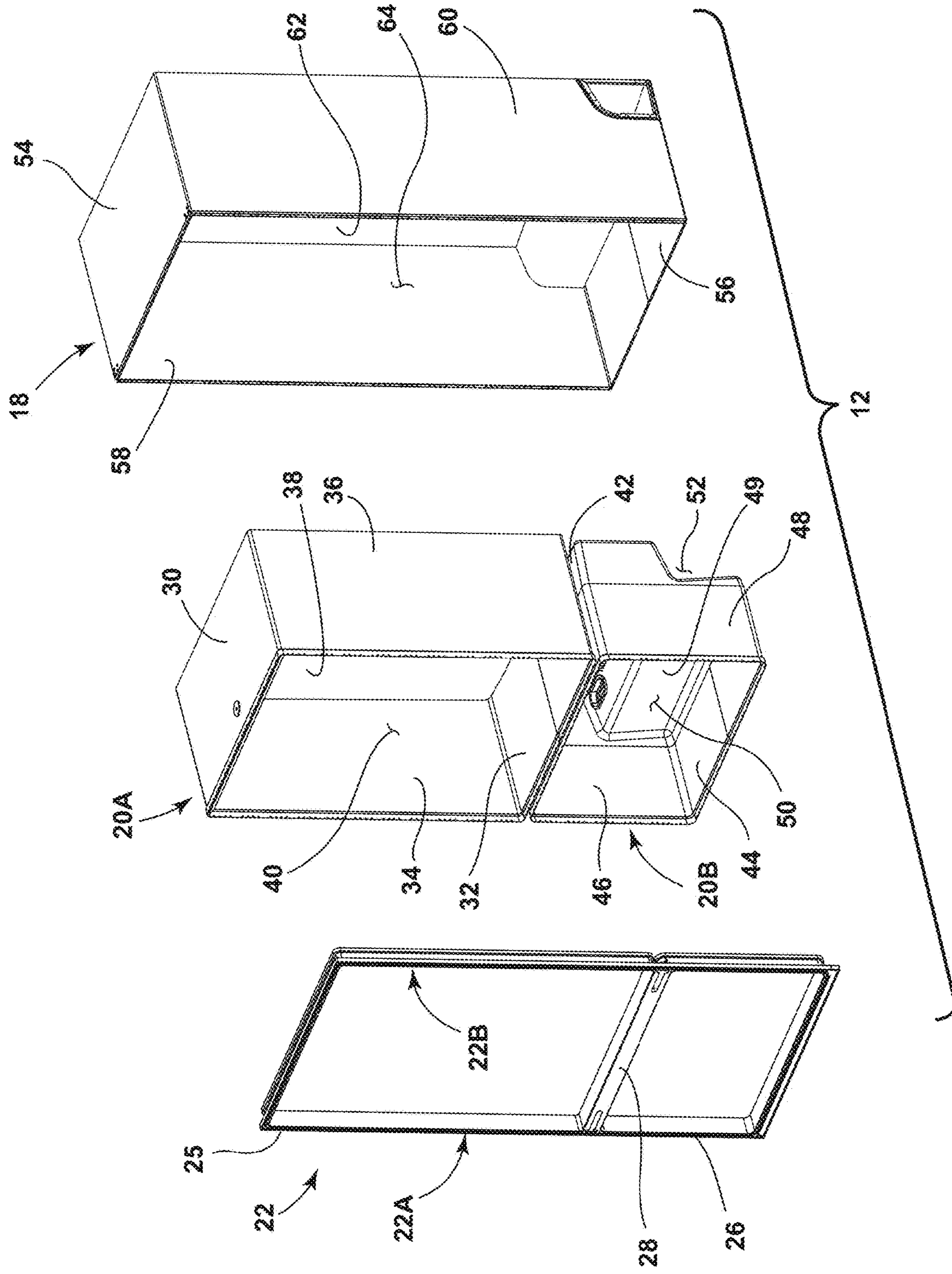


FIG. 1B

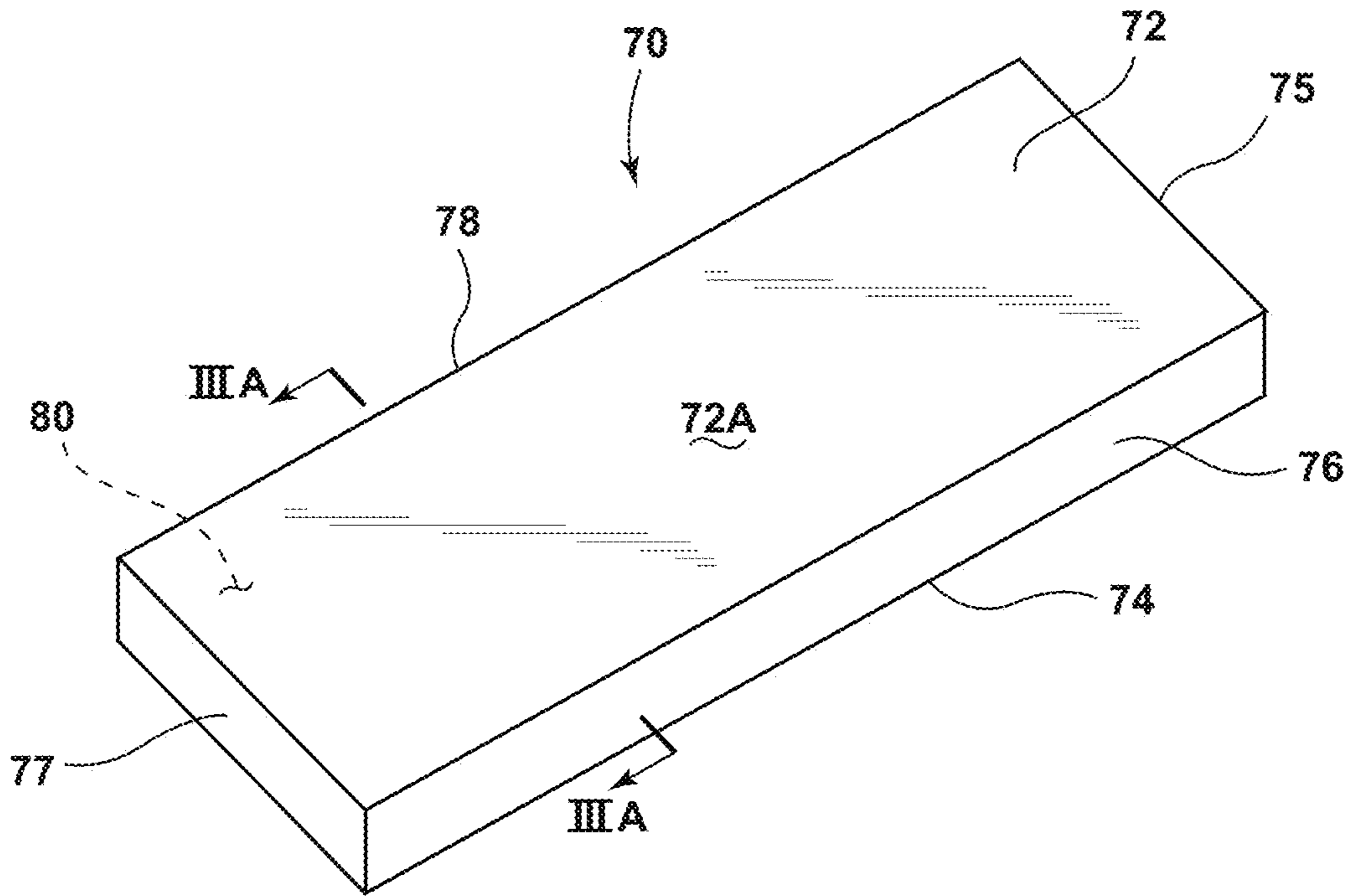


FIG. 2A

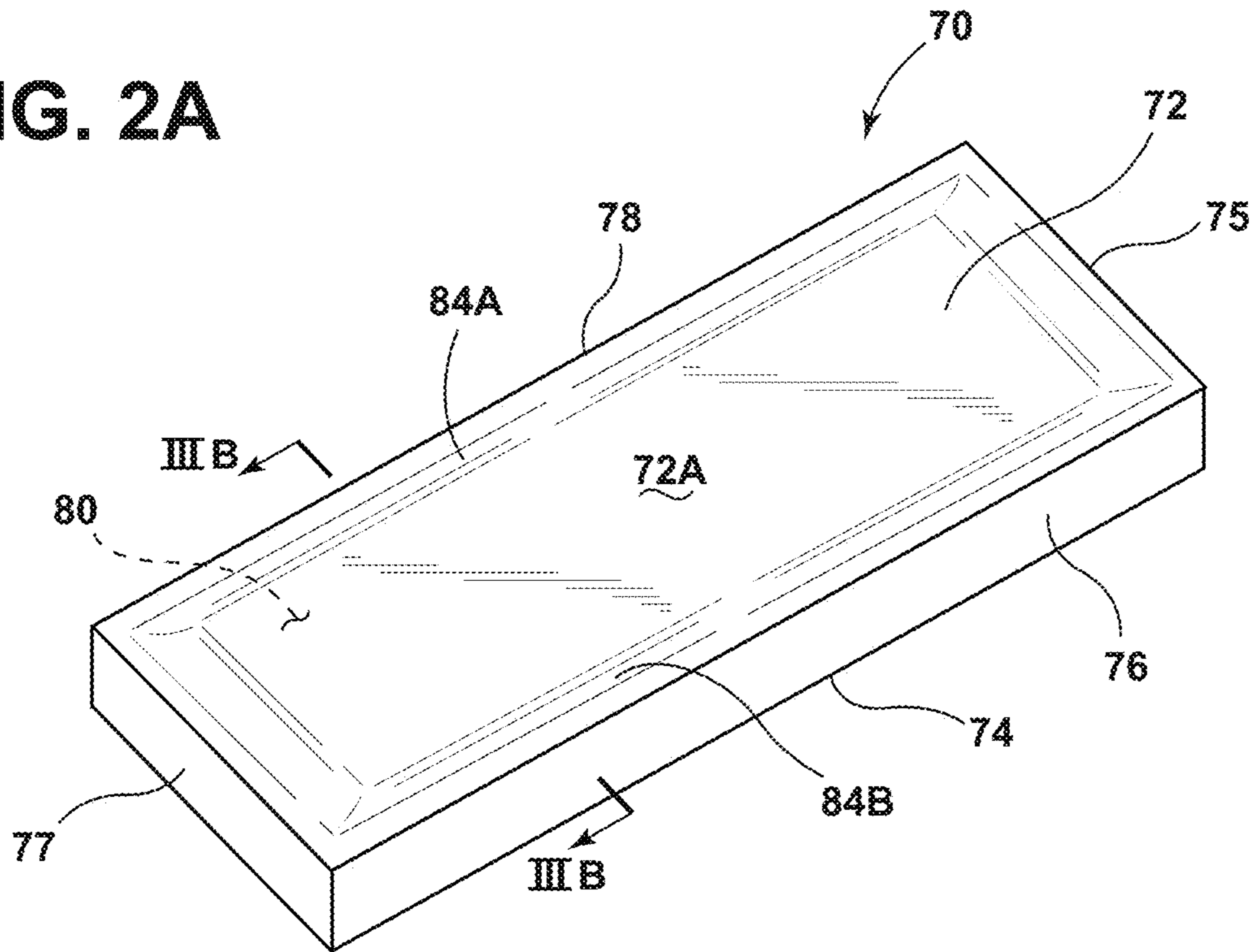


FIG. 2B

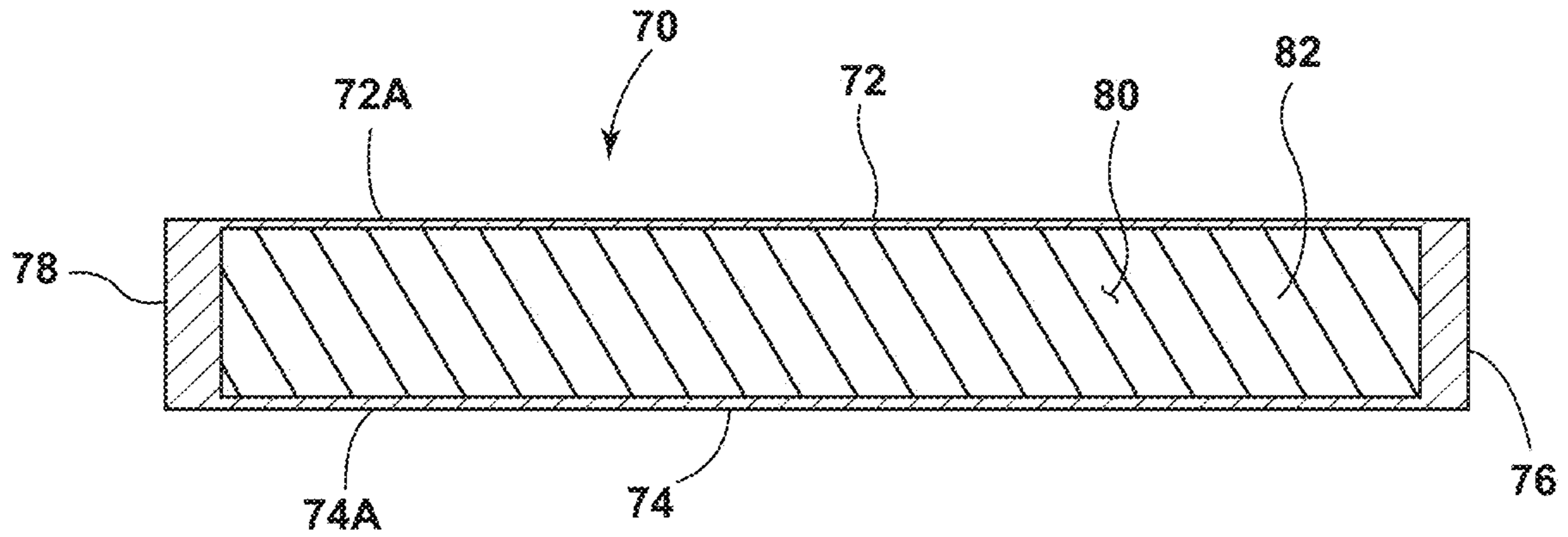


FIG. 3A

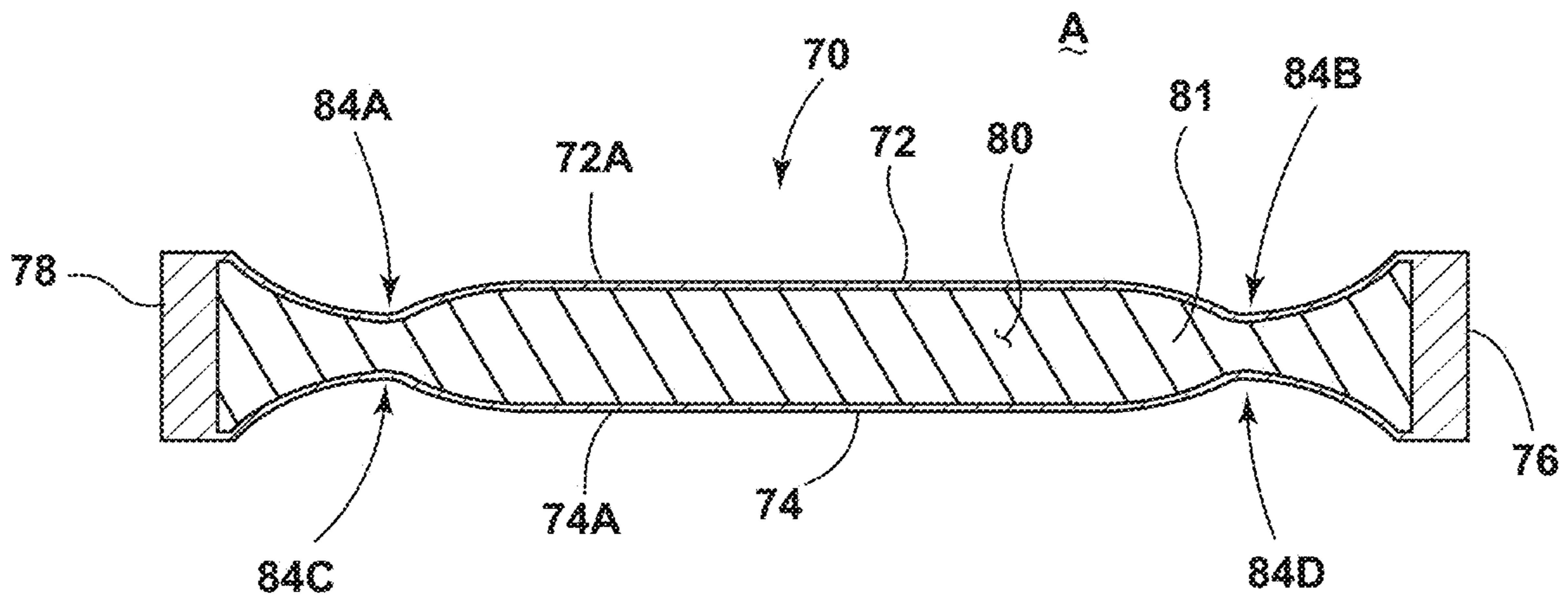


FIG. 3B

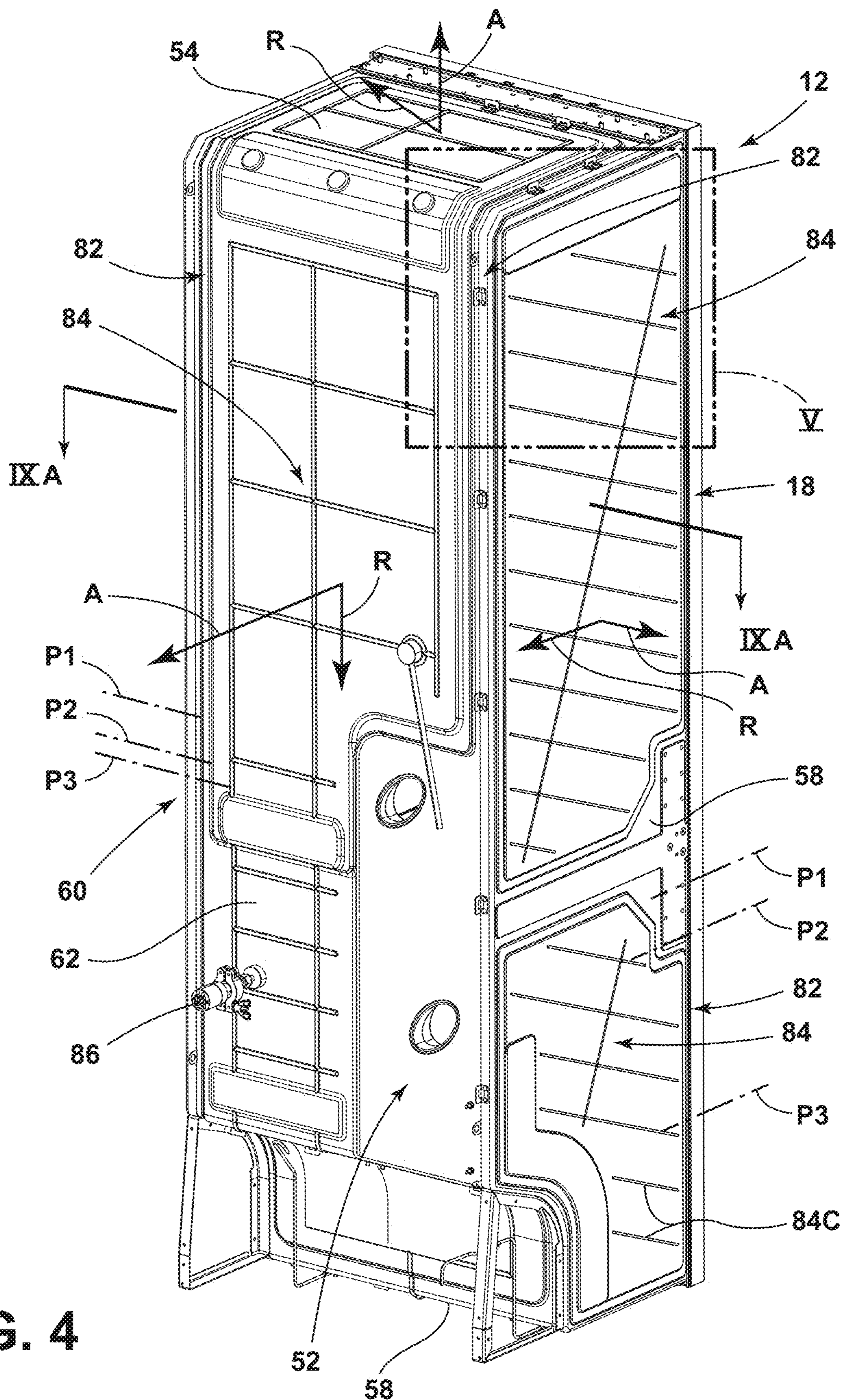


FIG. 4

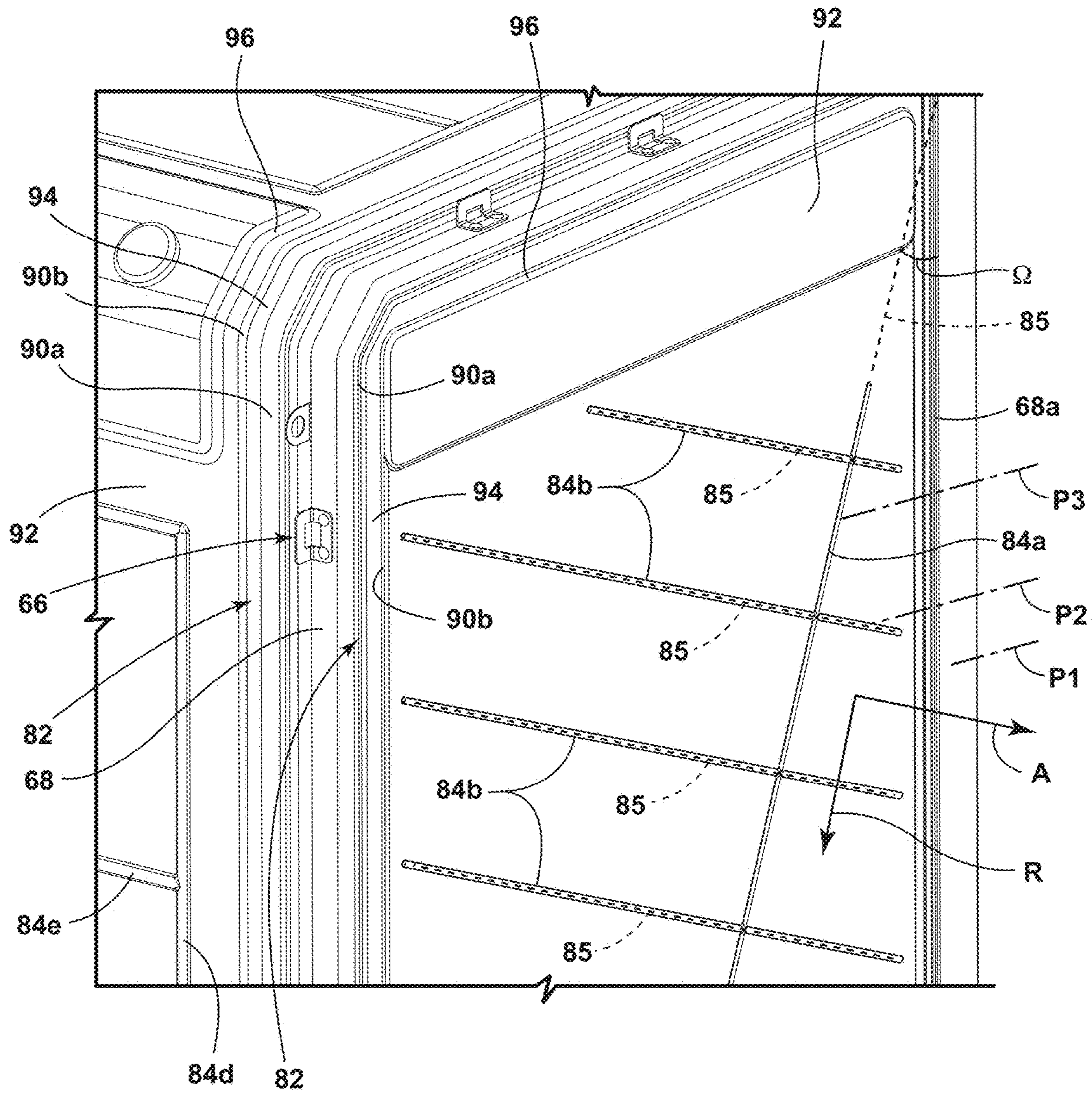


FIG. 5

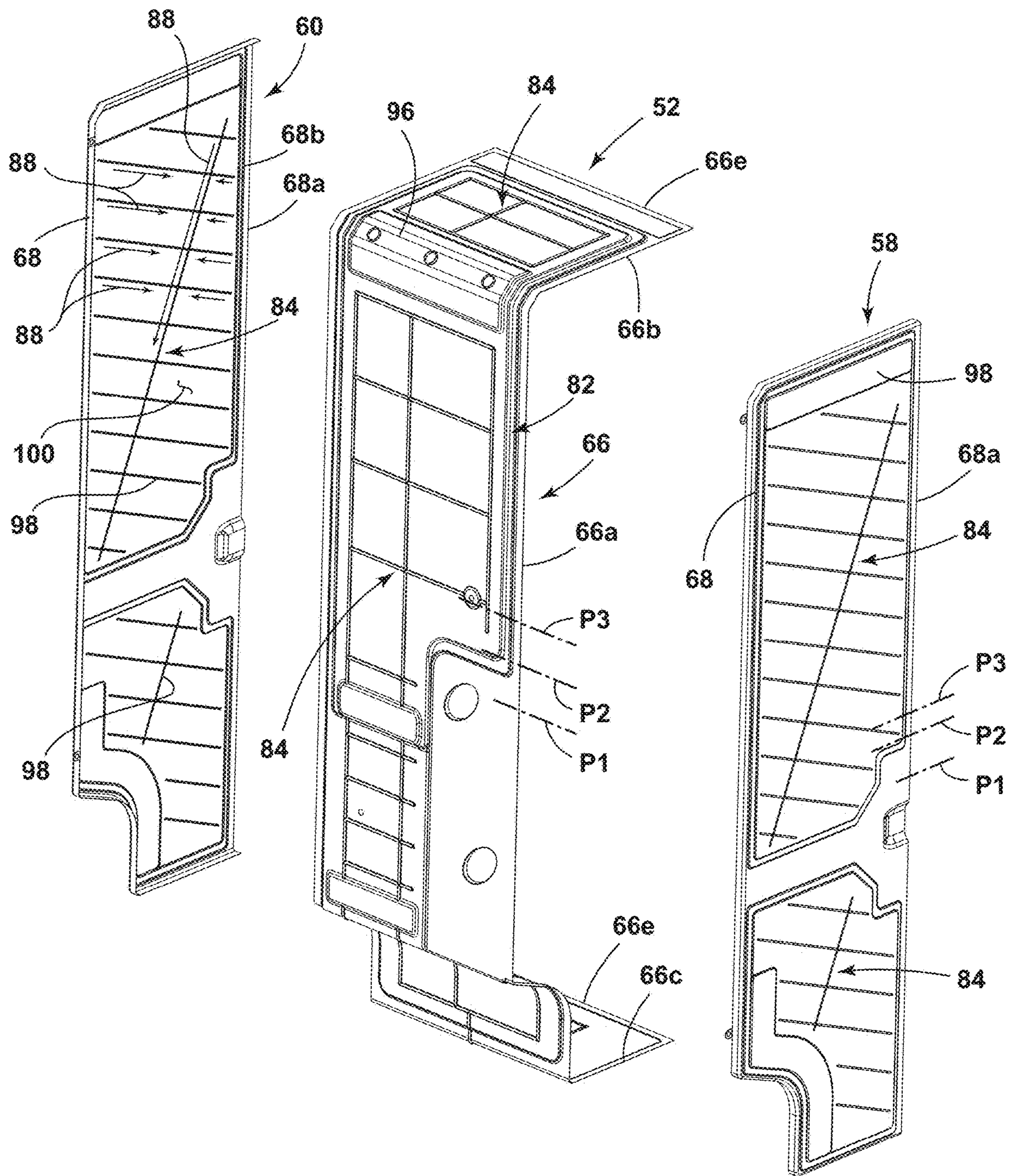


FIG. 6

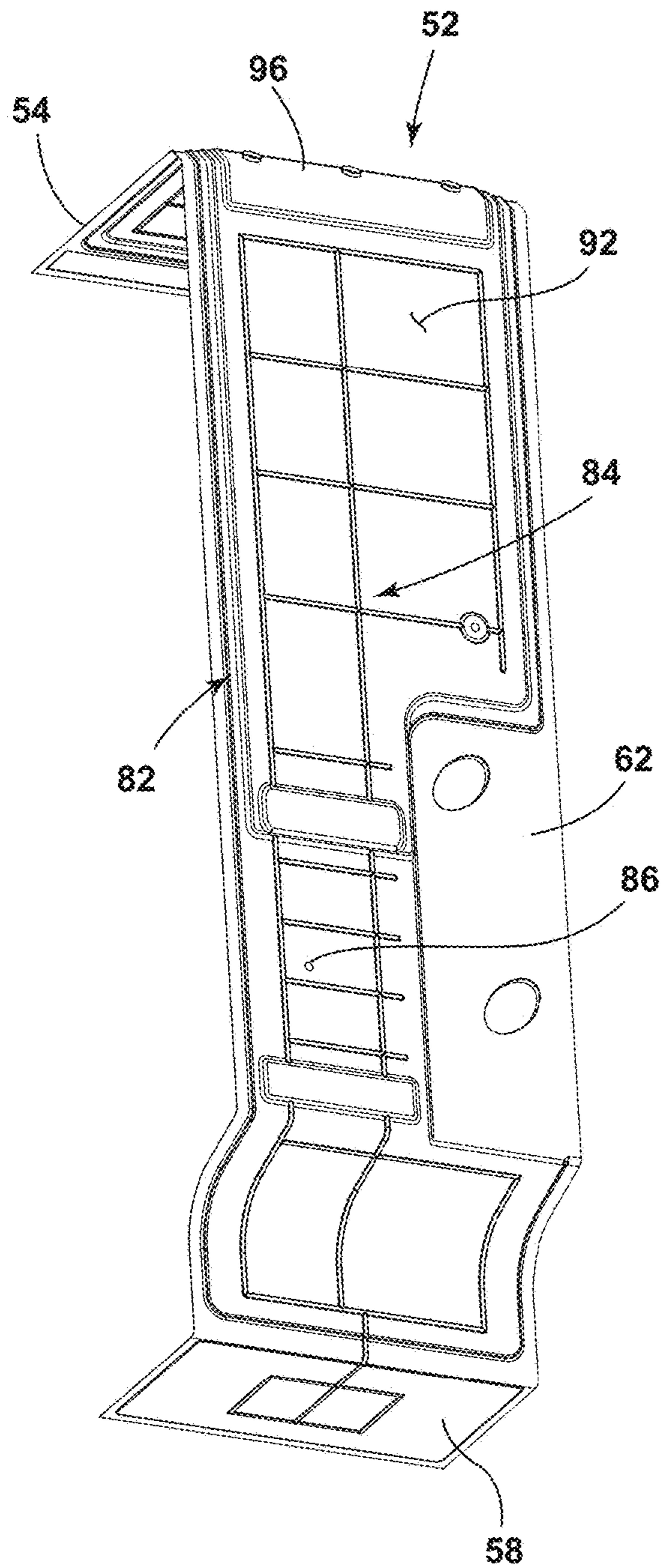


FIG. 7

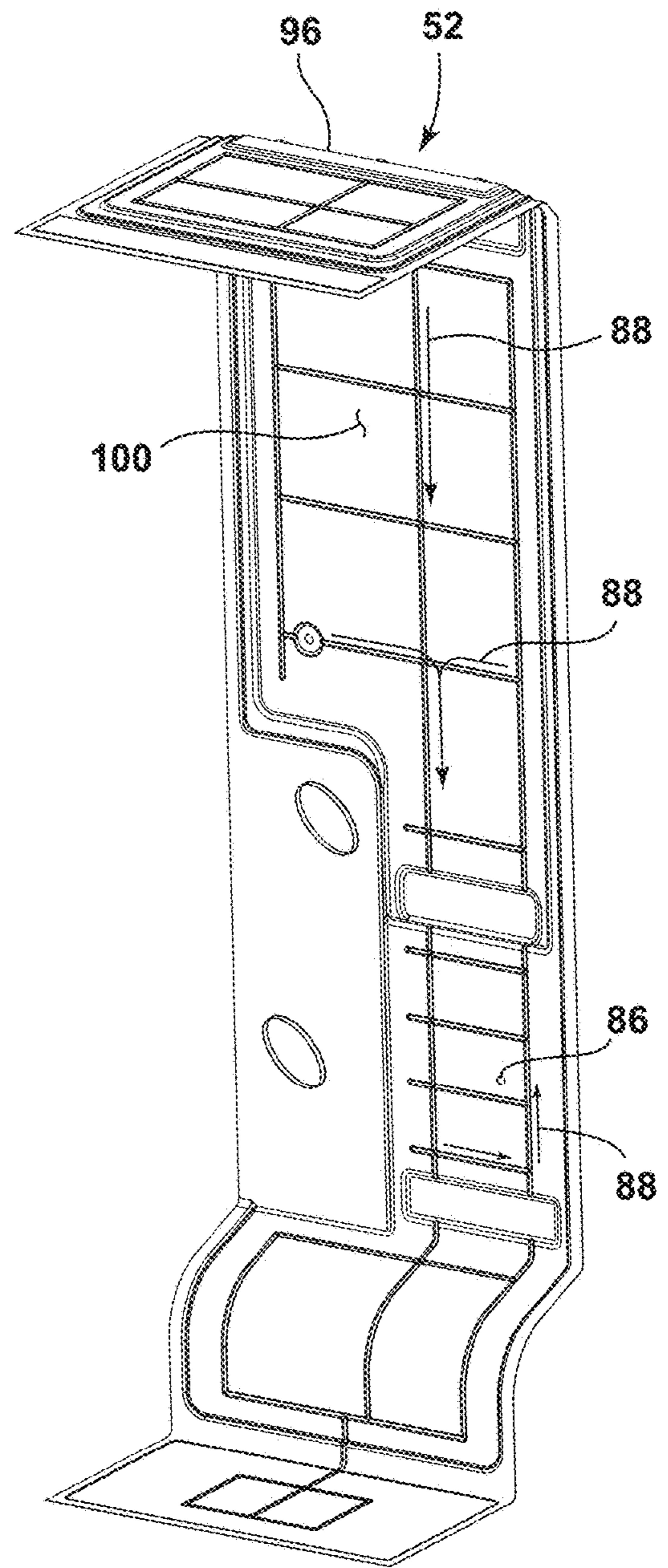


FIG. 8

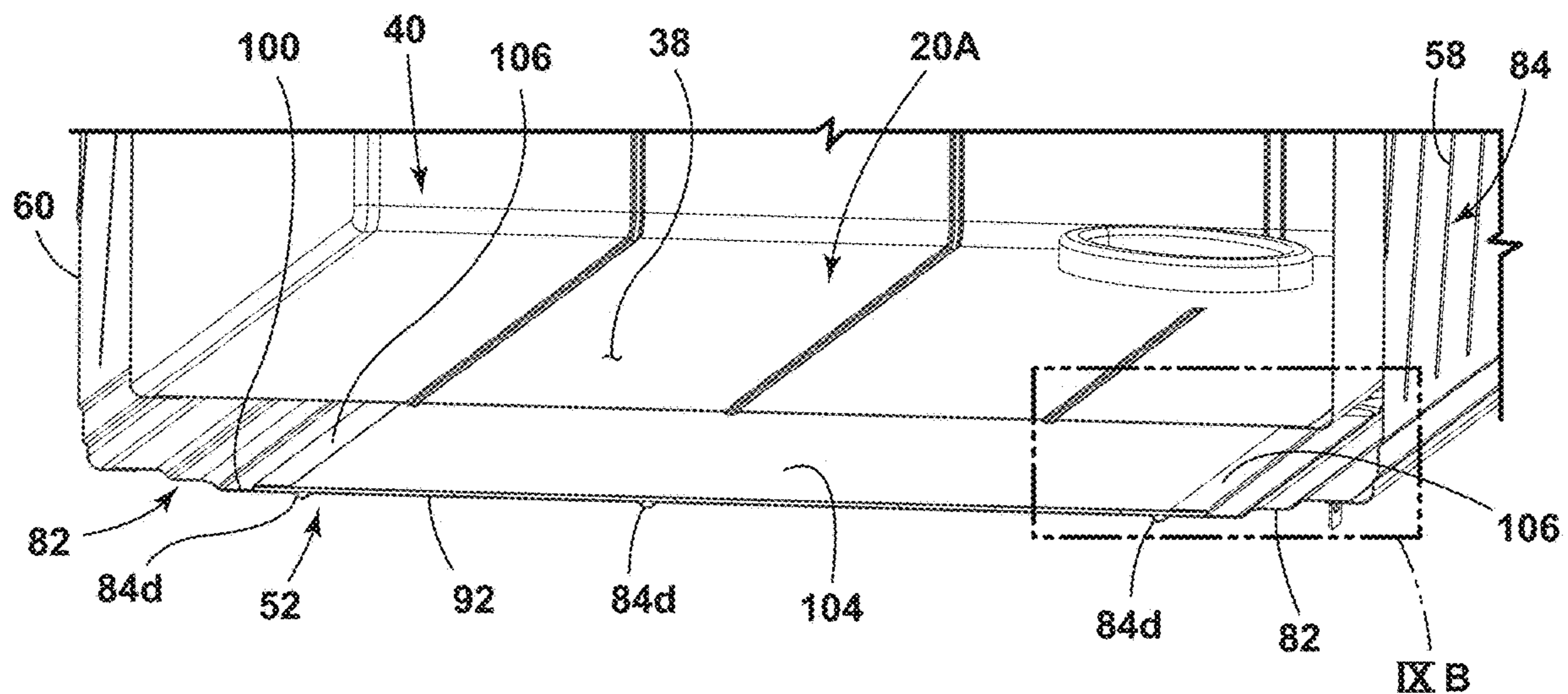


FIG. 9A

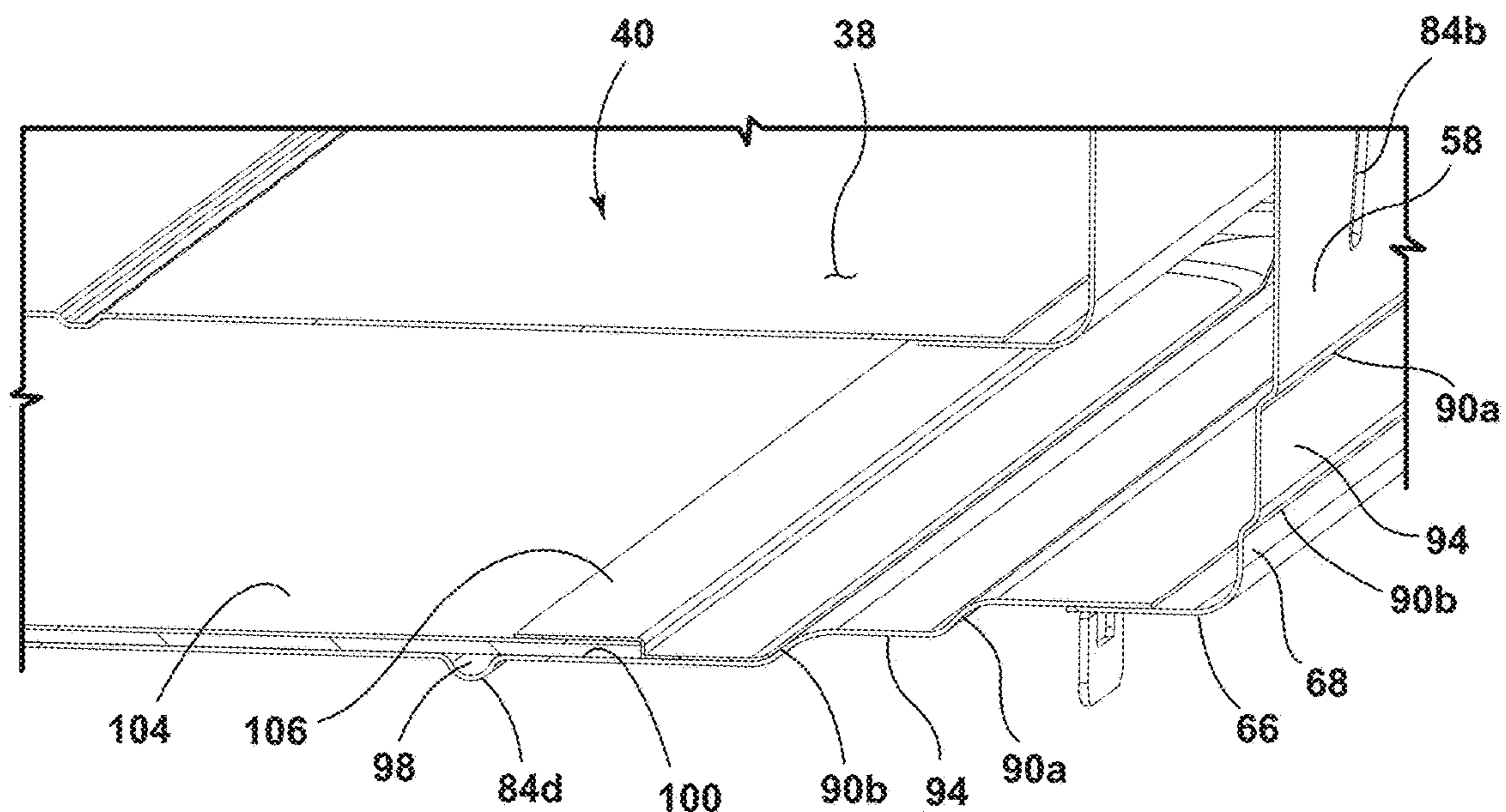


FIG. 9B

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**VACUUM INSULATED REFRIGERATOR
STRUCTURE WITH FEATURE FOR
CONTROLLING DEFORMATION AND
IMPROVED AIR WITHDRAWAL**

CROSS-REFERENCE TO RELATED
APPLICATIONS

The present application is a Continuation of U.S. patent application Ser. No. 17/146,546, now U.S. Pat. No. 11,448,355, filed on Jan. 12, 2021, and entitled "VACUUM INSULATED REFRIGERATOR STRUCTURE WITH FEATURE FOR CONTROLLING DEFORMATION AND IMPROVED AIR WITHDRAWAL," the entire contents of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE DISCLOSURE

The present disclosure generally relates to a vacuum insulated structure for a refrigerator, and more specifically, to cover member geometry for controlling the effects of vacuum evacuation on the structure.

SUMMARY OF THE DISCLOSURE

According to one aspect of the present disclosure, a vacuum insulated structure includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion. The vacuum insulated structure also includes a second cover member and a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the deformation control member and to define a portion of a path for air flow out of the sealed cavity during a vacuum draw process.

According to another aspect of the present disclosure, a refrigerator includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion. The deformation control member is configured as a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member. The rib extends along an axis disposed at an angle of between 15° and 75° with respect to an edge of the cover member comprising the perimeter portion. The refrigerator further includes a second cover member and a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the rib.

According to yet another aspect of the present disclosure, a refrigerator includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced

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axially outward and disposed radially inward of the perimeter portion. The deformation control member is configured as a stepped area defined by a stepped segment of the first cover member extending to the second planar level from toward the first planar level. The refrigerator further includes a second cover member, a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween, an insulating material disposed within the insulating cavity, and a mesh material layer received in the stepped area. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the deformation control member and to define a portion of a path for air flow out of the sealed cavity during a vacuum draw process. The mesh material layer is configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area.

According to yet another aspect of the present disclosure, a vacuum insulated structure including a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and first rib formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion, a second cover member, and thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first rib defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process.

According to yet another aspect of the present disclosure, a refrigerator including a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member. The first rib extends along an axis disposed at an angle of between 15° and 40° with respect to an edge of the cover member comprising the perimeter portion. The refrigerator further includes a second cover member and a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the open interior portion of the first rib defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process.

According to yet another aspect of the present disclosure, a refrigerator including a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a stepped area defined by a stepped segment of the first cover member disposed radially inward of the perimeter portion and extending to the second planar level from toward the first planar level, a second cover member, a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween, an insulating material disposed within the insulating cavity, and a mesh material layer received in the stepped area. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, the stepped area defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process, and the mesh material layer is configured to maintain the insulating material out of the first portion of the air flow path.

These and other features, advantages, and objects of the present disclosure will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1A is an isometric view of a refrigerator including a vacuum insulated cabinet structure;

FIG. 1B is an exploded perspective view of another vacuum insulated cabinet structure;

FIG. 2A is a top perspective view of a schematic vacuum insulated cabinet structure prior to a vacuum drawing procedure;

FIG. 2B is a top perspective view of the schematic vacuum insulated cabinet structure of FIG. 2A after a vacuum has been drawn;

FIG. 3A is a cross-sectional view of the schematic vacuum insulated cabinet structure of FIG. 2A taken at line IIIA;

FIG. 3B is a cross-sectional view of the schematic vacuum insulated cabinet structure of FIG. 2B taken at line IIIB;

FIG. 4 is a perspective view showing an implementation of a wrapper for the refrigerator of FIG. 1 configured to control deformation due to vacuum draw, according to an aspect of the present disclosure;

FIG. 5 is a perspective detail view of a portion of the wrapper of FIG. 4;

FIG. 6 is an exploded view of the wrapper of FIG. 4;

FIGS. 7 and 8 are perspective exterior and interior views of a central member of the wrapper, respectively; and

FIGS. 9A and 9B are cross-sectional and detail views of an interior of the vacuum insulated structure of the refrigerator.

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles described herein.

DETAILED DESCRIPTION

The present illustrated embodiments reside primarily in combinations of method steps and apparatus components related to a vacuum insulated structure for a refrigerator. Accordingly, the apparatus components and method steps have been represented, where appropriate, by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present disclosure so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein. Further, like numerals in the description and drawings represent like elements.

For purposes of description herein, the terms “upper,” “lower,” “right,” “left,” “rear,” “front,” “vertical,” “horizontal,” and derivatives thereof shall relate to the disclosure as oriented in FIG. 1. Unless stated otherwise, the term “front” shall refer to the surface of the element closer to an intended viewer, and the term “rear” shall refer to the surface of the element further from the intended viewer. However, it is to be understood that the disclosure may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the

appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

The terms “including,” “comprises,” “comprising,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by “comprises a . . .” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element. As used herein, the term “about” may be used to modify a dimension or other numeric value to indicate an approximate value that may, for example, encompass various manufacturing tolerance ranges and/or errors in measurement techniques and associated tools or devices, as are generally known in the art. Additionally or alternatively, the term “about” may indicate that the associated measurement of value may vary from that listed by $\pm 10\%$.

Referring to FIGS. 1A-9B, reference numeral **12** generally designates a vacuum insulated structure. The vacuum insulated structure **12** includes a plurality of cover members, each of a stamped unitary sheet. In this respect, the cover members can comprise the portions of the outer wrapper **18**, as well as the liners **20A** and **20B**, depicted in FIGS. 1A and 1B. In particular, as shown in FIGS. 4 and 6, the outer liner **18** can comprise separate cover members in the form of a central unitary structural member **52** that includes the top wrapper wall **54**, the rear wrapper wall **62**, and the bottom wrapper wall **56**, as well as two side members that entirely comprise each wrapper side wall **58** and **60**, with the members being generally and collectively referred to as “cover members.” At least one of the cover members **52** and each of the side members **58** and **60** define a perimeter portion **66,68** positioned at a first planar level, which may comprise either of the various planar levels, **P1** or **P2**, discussed further herein, and a deformation control member **82,84** formed in the unitary sheet extending to a second planar level, **P2** or **P3**, spaced outwardly from the first planar level in an axial direction **A** with respect to the sheet and disposed inward of the perimeter portion **66,68** in a radial direction **R** with respect to the sheet. The vacuum insulated structure **12** also includes a thermal bridge **22** interconnecting at least portions of the cover members (i.e., the central unitary structural member **52**, the side cover members **58,60**, the upper liner **30**, and the lower liner **32** at the perimeter portions **66,68** (as well as the perimeter portions **31,33** of the upper liner **30** and lower liner **32**, respectively) to define an insulating cavity **24** therebetween. The insulating cavity **24** is a sealed cavity having a vacuum drawn therefrom, and the deformation control members **82,84** are configured to reduce deformation of the cover members **52,58,60** in at least an area adjacent the respective deformation control member **82,84** and to define a portion of a path **88** for air flow out of the sealed cavity **24** during a vacuum draw process. In this manner, the present vacuum insulated structure **12** provides an outer wrapper **18** configured to provide a predictable or “controlled” vacuum bow deflection during vacuum draw by way of the deformation control members **82,84**. Additionally, the deformation control members **82,84** can limit or visually obscure deflection of the cover members **52,58,60**. In certain aspects, the deformation control members **82,84** can also promote air flow during vacuum evacuation of the

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vacuum insulated structure **12** or can accommodate additional elements or features to promote air draw, as discussed further below.

Referring now to FIG. 1A, a refrigerator **10** is shown having a vacuum insulated cabinet structure **12**. The vacuum insulated cabinet structure **12** includes one or more front openings **14A**, **14B** that may be closed off by doors **16A**, **16B** and **16C**. The doors **16A**, **16B** are contemplated to pivot between open and closed positions relative to upper front opening **14A**. As further found in the illustrated example, door **16C** is in the form of a sliding drawer which horizontally slides between open and closed positions for selectively providing access to the lower front opening **14B** of the insulated cabinet structure **12**.

As further shown in FIG. 1A, the vacuum insulated cabinet structure **12** includes an exterior wrapper **18** and upper and lower liners **20A**, **20B**. In the embodiment shown in FIG. 1A, the upper and lower liners **20A**, **20B** generally indicate a refrigerator compartment and a freezer compartment, respectively. In assembly, the upper and lower liners **20A**, **20B** are interconnected with the exterior wrapper **18** via a thermal bridge **22**. The thermal bridge **22** is best shown in FIG. 1B. As further shown in FIG. 1A, the exterior wrapper **18** is spaced-apart from the upper and lower liners **20A**, **20B** to define an insulating cavity **24** therebetween. The insulating cavity **24** is contemplated to be a sealed cavity that may comprise a vacuum core material such as a silica powder or other suitable loose filler material that is inserted (e.g., blown) into the insulating cavity **24** after the exterior wrapper **18**, upper and lower liners **20A**, **20B** and thermal bridge **22** have been coupled together.

Referring now to FIG. 1B, the vacuum insulated cabinet structure **12** is shown in an exploded view. The thermal bridge **22** of the vacuum insulated cabinet structure **12** includes first and second side members **22A** and **22B** along with upper and lower openings **25**, **26** which are configured to align with the upper and lower liners **20A**, **20B** in assembly. The thermal bridge **22** further includes a mullion portion **28** disposed between the upper and lower openings **25**, **26** and extending between the first and second side members **22A**, **22B**. The upper liner **20A** is shown having a top wall **30**, a bottom wall **32**, opposed side walls **34**, **36** and a rear wall **38** (collectively referred to herein as sidewalls) which all cooperate to define a refrigerator compartment **40**. Similarly, the lower liner **20B** includes a top wall **42**, a bottom wall **44**, interconnecting sidewalls **46**, **48** and a rear wall **49** which all cooperate to define a freezer compartment **50**. The rear wall **49** is shown having a stepped configuration to define a spacing **52** which may be used to house various cooling components for cooling both the refrigerator compartment **40** and the freezer compartment **50**. The upper and lower liners **20A**, **20B** may be comprised of a sheet metal material that is folded and welded to define the parameters of the refrigerator compartment **40** and the freezer compartment **50**.

As further shown in FIG. 1B, the exterior wrapper **18** includes a top wall **54**, a bottom wall **56**, opposed sidewalls **58**, **60** and a rear wall **62** (collectively referred to herein as sidewalls) which together cooperate to define a receiving cavity **64**. The exterior wrapper **18** may be comprised of a sheet metal material that is folded and/or welded to define the parameters of the receiving cavity **64** such that the wrapper **18** is generally of a unitary structure. In assembly, the upper and lower liners **20A**, **20B** are received in the receiving cavity **64** of the exterior wrapper **18**, such that the exterior surfaces of the upper and lower liners **20A**, **20B** cooperate with the inner surfaces of the exterior wrapper **18**

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to define the insulating cavity **24** disposed therebetween as shown in FIG. 1A. The insulating cavity **24** may directly receive an insulating material and have a vacuum drawn directly from the insulating cavity **24** to provide a vacuum insulated cabinet structure **12**. In this way, the vacuum insulated cabinet structure **12** may include an overall thinner profile to maximize the amount of space available for the refrigerator compartment **40** and the freezer compartment **50** in assembly.

Referring now to FIG. 2A, a schematic assembly **70** is used to describe a deformation effect of a vacuum drawing procedure. The assembly **70** includes first and second cover members **72**, **74** that are spaced-apart from one another and interconnected by side members **75-78**. The side members **75-78** may be side members of a unitary frame structure to which the first and second cover members **72**, **74** are attached. The assembly **70** includes a cavity **80** defined by the first and second cover members **72**, **74** as spaced-apart from one another and interconnected by side members **75-78**. The cavity **80** may be filled with a particulate material, such as a compressed cake of activated carbon black or silica gel, or a mixture of the two. These fillers are designed to fill the cavity **80** and are placed therein before a vacuum is drawn on the assembly **70**. The filler is indicated by reference numeral **81** and is best shown in FIG. 3A.

Referring now to FIG. 2B, the schematic assembly **70** has had a vacuum drawn on the cavity **80**, such that the cavity **80** now defines an evacuated cavity **80**. By drawing the vacuum on the schematic assembly **70**, the first and second cover members **72**, **74** have inwardly collapsed towards each other, thereby providing for a deformed outer surface **72A** of first cover member **72** as shown in FIG. 2B. The deformation of the schematic assembly **70** shown in FIG. 2B is best depicted in FIG. 3B.

Referring now to FIG. 3A, the cross-sectional view of the schematic assembly **70** shown in FIG. 2A is depicted, wherein the outer surface **72A** of the first cover member **72** and an outer surface **74A** of the second cover member **74** are shown in substantially planar configurations between side members **78**, **76**. This configuration shown in FIG. 3A is an ideal configuration for a vacuum insulated structure after a vacuum has been drawn on the schematic assembly **70**. However, as noted above, when a vacuum is drawn on the schematic assembly **70** of FIGS. 2A and 3A, a deformed schematic assembly **70**, as shown in FIGS. 2B and 3B, is often the result. With specific reference to FIG. 3B, the outer surfaces **72A**, **74A** of the first and second cover members **72**, **74** are no longer planar outer surfaces, but rather inwardly deformed outer surfaces having specific indent deformations **84A-84D** which draw the first and second cover members **72**, **74** towards one another due to the low pressure of the evacuated cavity **80**. The pressure within the evacuated cavity of assembly **70** is contemplated to be less than 10 mbar as compared to an atmospheric pressure of 1 atm or 1013.25 mbar.

In an effort to avoid the vacuum deformation bow shown in the schematic assembly **70** of FIGS. 2A-3B, the present concept includes a vacuum insulated structure having an area configured for controlled deformation. Referring to FIGS. 4-9B, the above-mentioned plurality of cover members are shown, each in the form of a stamped unitary sheet. The outer liner **18** is shown as comprising cover members in the form of a central unitary structural member **52** that includes the top wrapper wall **54**, the rear wrapper wall **62**, and the bottom wrapper wall **56**, as well as two side members that entirely comprise each wrapper side wall **58** and **60**. As shown in FIGS. 4 and 5, both the central unitary

structural member **52** and each of the side members **58** and **60** define a perimeter portion **66,68** positioned at a first planar level **P1** and a deformation control member **82,84** formed in the unitary sheet extending to a second planar level **P2** spaced outwardly from the first planar level **P1** in an axial direction **A** with respect to the sheet and disposed inward of the perimeter portion **66,68** in a radial direction **R** with respect to the sheet (notably, the radial direction **R** is depicted as a single vector but may correspond with any co-planar vector that is perpendicular to and radiates from the vector designating the axial direction **A**).

The vacuum insulated structure **12** also includes the thermal bridge **22**, such as depicted in FIGS. **1A** and **1B**, interconnecting the first cover members (i.e., the central unitary structural member **52**, the side cover members **58,60**, the upper liner **30**, and the lower liner **32** at the perimeter portions **66,68** (as well as the perimeter portions **31,33** of the upper liner **30** and lower liner **32**, respectively) to define the insulating cavity **24** therebetween. The deformation control members **82,84** are configured to reduce deformation of the cover members **52,58,60** in at least the areas adjacent the respective deformation control member **82,84** and to define respective portions of a path **88** for air flow out of the sealed cavity **24** during a vacuum draw process.

As mentioned above, and as shown in FIG. **6**, the above-mentioned cover members include unitary sheets comprising the sides **58** and **60** of the wrapper **18**, as well as the central unitary structural member **52**. The side cover members **58** and **60** are attached along portions of their respective outer perimeters **68** to corresponding portions of the perimeter **66** of the central member **52**. As shown, the portions of the perimeters **68** of the side members **58,60** that are attached with the perimeter **66** of the central member **52** define respective edge portions **68a,68b,68c** of the perimeter **68** that align with the top wall **54**, rear wall **62**, and bottom wall **56** of the wrapper **18**, as defined on the central member **52**. In this manner, remaining front-top **66a**, front-bottom **66b**, and front **68d** edges of the central member **52** and side members **58** and **60**, respectively remain for coupling with the thermal bridge **22** to enclose the cavity **24** by way of additional coupling with the remaining cover members in the form of the upper liner **30** and lower liner **32** (with other configurations possible, depending on the particular configuration of refrigerator **10**). In such a configuration, it can be appreciated that the central member **52**, in particular, may define multiple first planar levels **P1**, as the entire outer perimeter **66** thereof follows the shape of the central member **52** around the various walls **54,56,58** of the wrapper **18** defined thereon, the various perimeter planar levels designated as **P1**, and corresponding axial **A** and radial **R** directions, being established with respect to the portions of the perimeter **66** that correspond with the portions thereof surrounding the subject walls **54,56,68**. In one aspect of the construction of wrapper **18**, the side cover members **58,60** can be welded to the central unit **52**, and the resulting outer wrapper **18** to give the wrapper **18** a unitary, impermeable configuration.

Prior to sealing of cavity **24**, which may be achieved by sealingly coupling thermal bridge **22** over the liners **22A, 22B** and the assembled outer wrapper **18**, the cavity **18** can be filled with an insulating filler material in the form of various powders or granular particles that can generally fill the space that comprises the cavity **24**. In particular, the insulating filler material can be open celled foam or a microporous filler material which may optionally include particulate reflectors or opacifiers, such as aluminum, flake or carbon black, to reduce transmission of radiation energy

through the vacuum insulated structure **12**. The cavity **100** may also be filled with an insulating material in the form of a powder comprised of fumed silica, glass beads, processed rice husks, or any combination thereof. The insulating material is contemplated to have a conducting coefficient or thermal conductivity of at least **5 mW/mK**, or lower, to ensure that the insulating properties of the vacuum insulated structure **12** are sound.

The assembled vacuum insulated structure **12** is then subjected to an evacuation process, wherein the cavity **24**, accessed via port **86** to draw a vacuum from the cavity **24**, thereby providing a low pressure environment within the cavity **24**. The low pressure environment of the cavity **24** may include a reduced internal pressure of less than **10 mbar**, but may include other pressure settings conditioned on a filler material used in the vacuum insulated structure **12**, and also conditioned on the desired insulative value of the vacuum insulated structure **12**. As discussed above, the withdrawal of air from cavity **24** and the resulting low pressure environment of cavity **24** causes inwardly-directed forces to be applied to the various walls **54,56,58,60** of the wrapper **18** and the walls **42,44,46,48** of the liners **20A** and **20B**. As mentioned above, at least some of the walls **54,56,58,60** of the wrapper **18** are configured to direct a majority of the deformative effects of the inwardly-directed forces to within certain areas and to limit the overall deflection to within a specified overall distance. In one such aspect, the central member **52** and the side members **58,60** each include a deformation control member **82** in the form of one or more stepped areas thereof that are each generally defined by a stepped segment **90** that extends to an outward planar level **P2** from toward the perimeter planar level **P1**. In this manner, each of the central member **52** and the side members **58,60** each include an inner surface portion **92** framed by the stepped areas **82**, with the inner surface portions **92** being positioned along the outward planar level **P2**.

As shown in the detail view of FIG. **5**, the stepped areas **82** can include multiple steps between the perimeter planar level **P1** and the outward planar level **P2**. In particular, the stepped areas **82** can include a first stepped segment **90a** extending from the perimeter planar level **P1** toward the outward planar level **P2** and a second stepped segment **90b** extending from a position generally aligned with an outward-most portion of the first stepped segment **90a** and to the outward planar level **P2**. The stepped segments **90a** and **90b** can be connected by an intermediate face segment **94** that extends generally parallel to the planar levels **P1** and **P2**. In this manner, the orientation of the stepped segments **90a** and **90b** in a position generally perpendicular to the planar levels **P1** and **P2** can strengthen the adjacent areas of the cover members **52, 56, and 58**. Additionally, the presence of multiple stepped segments **90a** and **90b** connected by the face segment **94** can allow the stepped area **82** to collapse inwardly under the inwardly-directed forces generated by the vacuum draw. This can occur by inward flexing of the face segment **94** such that the second stepped segment **90b** can move inwardly in a direction generally parallel with the first stepped segment **90a** in a generally fan-fold type manner. Additional deformation of the cover member **52, 56, or 58** may occur between the perimeter portion **66** or **68** and the first stepped segment **90a** or within the inner face **92** in an area immediately adjacent the second stepped segment **90b**. In general, the appearance of deformations in such areas may be less noticeable to an observer by being visually obscured by the adjacent visual features of the stepped area **82**. As also shown in FIGS. **4** and **5**, the central member **52**

may include an additional stepped area **96** that extends to an additional planar level **P3** disposed outward of the outer planar level **P2**. Such additional stepped area **96** can wrap around a portion of central member **52** that includes portions of both the top wall **54** and the rear wall **62** and may provide additional reinforcement of central member **52** and/or additional air flow during vacuum deformation in a manner discussed further below.

As also mentioned above, a further deformation control member is configured as rib **84** that can be positioned along either or both of central member **52** and side members **58** and **60**. In particular, the various ribs **84** are positioned along the inner surface portions **92** of the various cover members **52,58**, and **60** within the stepped areas **82** and extend from the outward planar level **P2** to an additional planar level **P3** positioned further outward from the outward planar level **P2** in the axial direction **A**. In one aspect, the ribs **84** can provide structural reinforcement for the inner surface portions **92** such that deflection therealong from the above-described vacuum draw. As can be appreciated, this effect further limits the overall deformation of the cover members **52, 58**, and **60** to within the stepped areas **82**. Additionally, the presence of the ribs **84**, particularly in the illustrated grid patterns, described further below, further serves to visually obscure any deformation that may occur within the inner surface portions **92**. In general, the configuration of deformation control members **82** and **84** discussed herein can limit overall deformation of the cover members **52, 58**, and **60** to within about 2 mm (for example, as measured at a central point within the inner surface portions **92**) of inward deflection relative to the outward planar level **P2**.

As shown, the various depicted ribs **84** define an open interior portion **98** that extend outwardly from an interior surface **100** of the respective cover member **52,58**, or **60**, respectively, in the axial direction **A**. The ribs **84** each extend along a respective axis **85**. As shown, the side members **58,60** each include one or more ribs **84a** that extend at an oblique angle Ω of between 10° and 40° with respect to the adjacent front edge **68a** of the side member **58,60**. As shown, each such side member **58,60** defines two such oblique ribs **84a** that, in the illustrated example extend at about 30° with respect to the front edge **68a**, but may include more such ribs **84a**, depending on the particular configuration of the refrigerator **10**. Associated with each such oblique rib **84a** are a group of secondary ribs **84b**, the axes **85** of which extend in a direction oriented between 80° and 100° relative to the direction of the oblique ribs **84a**. In the illustrated example, the secondary ribs **84b** are oriented at a 90° angle relative to the oblique ribs **84a** and intersect a respective one of the oblique ribs **84a** at various points therealong. In this manner, the respective open interior portions **98** of the secondary ribs **84b** are connected and in communication with the open interior portion of the corresponding oblique rib **84a** such that the open interior portions, individually and collectively, define further respective portions of the path **88** for air flow out of the sealed cavity **24** during the vacuum draw process. Additional secondary ribs **84c** may be separate from the oblique ribs **84a** to maintain visual consistency along the inner surface portion **92**. The ribs **84** within the central member **52** may include horizontal ribs **84d** and vertical ribs **84e** that also define open interior portions **98** that intersect to define an additional network of interconnected portions of the air flow path **88**.

As discussed above, the sealed cavity **24** may be filled with an insulating material prior to sealing and vacuum draw. Notably, during vacuum draw, the inward deformation of portions of the various cover members, including of

central member **52** and side members **58** and **60**, as well as any deformation that may occur within various portions of liners **20A** and **20B** may compress the insulating material such that any voids therein or space between particles may be restricted or partially closed. In one aspect, the vacuum draw process pulls air from and through such voids or open spaces such that the closure or restriction thereof may inhibit the vacuum draw process, either requiring more time to complete vacuum draw or making the desired final pressure level more difficult to achieve. In this manner, the grid formation of ribs **84a** and **84b**, as well as **84d** and **84e** may provide areas where any filler material within the open interiors **98** thereof is compressed to a lesser extent during vacuum draw such that the corresponding portions of the air flow path **88** remain relatively unobstructed such that air may, at least in part, be drawn from adjacent portions of the filler material within the cavity **24** into the open interior portions **98** to provide a less obstructed path **88** for air flow than may otherwise be realized.

Additionally, as shown in FIGS. **9A** and **9B**, an interior area **102** of cavity **24** defined within the stepped areas **82** (i.e. along the interior of inner surface portion **92**) can receive a mesh material layer **104** therein. In one aspect, the mesh material layer **104** can be generally rigid, so as to resist compression during the vacuum draw process, and porous. Due to its rigidity, the mesh material layer **104** can maintain its porosity during the vacuum draw process and can maintain the insulating material out of the interior area **102** during the vacuum draw process such that an additional route for air flow out of cavity **24** is provided. As shown, the mesh material layer **104** can overlie the port **86** such that air drawn therethrough, in particular, has a relatively unobstructed path to the port **86**. The mesh material layer **104** can be held to the interior area **102** with one or more strips of filter paper **106** that may be adhered to a portion of the mesh material layer **104** and an adjacent portion of the interior surface **100** of the central member **52**, including within the stepped area **82**. Similar to the mesh material layer, the filter paper **106** may be air permeable but can have a small enough void or pore size to not be permeated by the adjacent insulating material.

The invention disclosed herein is further summarized in the following paragraphs and is further characterized by combinations of any and all of the various aspects described therein.

According to another aspect of the present disclosure, a vacuum insulated structure includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion. The vacuum insulated structure also includes a second cover member and a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the deformation control member and to define a portion of a path for air flow out of the sealed cavity during a vacuum draw process.

The deformation control member is configured as a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member. The rib extends along an axis disposed at an angle of between 15°

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and 40° with respect to an edge of the cover member comprising the perimeter portion.

The axis of the first rib is disposed at about 30° with respect to the edge.

The first rib is one of a plurality of ribs comprising a first group of ribs extending in a first direction and a second group of ribs extending in a second direction oriented between 30° and 50° relative to the first direction.

Each of the ribs define respective open interior portions extending axially outward of an inner surface of the first cover member portion to define further respective portions of the path for air flow out of the sealed cavity during the vacuum draw process.

The vacuum insulated structure further includes an insulating material disposed within the insulating cavity. The path for air flow out of the sealed cavity during the vacuum draw process facilitates removal of air from within the insulating material.

The first deformation control member is a stepped area defined by a stepped segment of the first cover member extending to the second planar level from toward the first planar level. The vacuum insulating structure further includes a mesh material layer received in the stepped area and configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area.

The vacuum insulated structure further includes an air permeable member adhered between a portion of the mesh material layer and a portion of an interior surface of the first cover member.

According to yet another aspect, a refrigerator includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion. The deformation control member is configured as a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member. The rib extends along an axis disposed at an angle of between 15° and 40° with respect to an edge of the cover member comprising the perimeter portion. The refrigerator further includes a second cover member and a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the rib.

The open interior portion of the first rib defines a portion of a path for air flow out of the sealed cavity during a vacuum draw process.

The first rib is one of a plurality of ribs comprising a first group of ribs extending in a first direction and a second group of ribs extending in a second direction oriented between 30° and 50° relative to the first direction. Each of the plurality of ribs define respective, interconnected open interior portions to further define the path for air flow.

The axis of the first rib is disposed at about 30° with respect to the edge

The first cover member is a side wall of an outer wrapper of the refrigerator, the second cover member is an inner liner disposed inward of the outer wrapper, and the thermal bridge surrounds an opening to an inner cavity of the refrigerator defined by the inner liner. The refrigerator further includes at least one door operably closing the opening.

The first cover member is a side wall of an outer wrapper of the refrigerator, and the second cover member is a unitary

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structural portion of the outer wrapper that defines a rear wall, a top wall, and a bottom wall of the outer wrapper. The second cover member is coupled to the first cover member along bottom, rear, and side edges of the perimeter portion.

The thermal bridge interconnects the first cover member and the second cover member between a front edge of the first cover member and both a top-front edge and a bottom-front edge of the second cover member.

The second cover member defines a stepped area defined by a stepped segment of the second cover member within at least one of the rear wall and the top wall.

According to yet another aspect, a refrigerator includes a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a deformation control member formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion. The deformation control member is configured as a stepped area defined by a stepped segment of the first cover member extending to the second planar level from toward the first planar level. The refrigerator further includes a second cover member, a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween, an insulating material disposed within the insulating cavity, and a mesh material layer received in the stepped area. The insulating cavity is a sealed cavity having a vacuum drawn therefrom, and the first deformation control member is configured to reduce deformation of the first cover member in at least an area adjacent the deformation control member and to define a portion of a path for air flow out of the sealed cavity during a vacuum draw process. The mesh material layer is configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area.

The refrigerator further includes an air permeable member adhered between a portion of the mesh material layer and a portion of an interior surface of the first cover member.

The stepped segment of the deformation control member is a first stepped segment.

The stepped area is further defined by a second stepped segment extending from the first planar level toward the second planar level, and the second stepped segment is disposed radially inward of the first stepped segment.

The first cover member is a unitary structural portion of an outer wrapper of the refrigerator that defines a rear wall, a top wall, and a bottom wall of the outer wrapper. The stepped area is a first stepped area, and the first cover member defines a second stepped area within the top wall of the unitary structural portion. The second cover member is a side wall of an outer wrapper of the refrigerator and is coupled to the first cover member along bottom, rear, and side edges of the perimeter portion. The thermal bridge interconnects the first cover member and the second cover member between a front edge of the first cover member and both a top-front edge and a bottom-front edge of the second cover member.

The second cover member includes a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member. The rib extends along an axis disposed at an angle of between 15° and 40° with respect to an edge of the cover member comprising the perimeter portion.

It will be understood by one having ordinary skill in the art that construction of the described disclosure and other components is not limited to any specific material. Other

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exemplary embodiments of the disclosure disclosed herein may be formed from a wide variety of materials, unless described otherwise herein.

For purposes of this disclosure, the term “coupled” (in all of its forms, couple, coupling, coupled, etc.) generally means the joining of two components (electrical or mechanical) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally formed as a single unitary body with one another or with the two components. Such joining may be permanent in nature or may be removable or releasable in nature unless otherwise stated.

It is also important to note that the construction and arrangement of the elements of the disclosure as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements shown as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present innovations. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the desired and other exemplary embodiments without departing from the spirit of the present innovations.

It will be understood that any described processes or steps within described processes may be combined with other disclosed processes or steps to form structures within the scope of the present disclosure. The exemplary structures and processes disclosed herein are for illustrative purposes and are not to be construed as limiting.

What is claimed is:

1. A vacuum insulated structure, comprising:

a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and first rib formed in the unitary sheet extending to a second planar level spaced axially outward and disposed radially inward of the perimeter portion and further defining a stepped area including a stepped segment of the first cover member extending to the second planar level from the first planar level and defining a second portion of the path for air flow out of the sealed cavity, the vacuum insulating structure further including;

a second cover member;

a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween, wherein the insulating cavity is a sealed cavity having

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a vacuum drawn therefrom, and further wherein the first rib defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process;

an insulating material disposed within the insulating cavity, wherein the path for air flow out of the sealed cavity during the vacuum draw process facilitates removal of air from within the insulating material;

a mesh material layer received in the stepped area and configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area; and

an air permeable member adhered between a portion of the mesh material layer and a portion of the inner surface of the first cover member.

2. The vacuum insulated structure of claim 1, wherein the first rib defines an open interior portion extending axially outward of an inner surface of the first cover member and extends along an axis disposed at an angle of between 15° and 40° with respect to an edge of the first cover member comprising the perimeter portion.

3. The vacuum insulated structure of claim 2, wherein the axis of the first rib is disposed at about 30° with respect to the edge.

4. The vacuum insulated structure of claim 3, wherein the first rib is one of a plurality of ribs comprising a first group of ribs extending in a first direction and a second group of ribs extending in a second direction oriented between 80° and 100° relative to the first direction.

5. The vacuum insulated structure of claim 4, wherein each of the plurality of ribs respectively defines the open interior portion thereof so as to extend axially outward of the inner surface of the first cover member such that the plurality of ribs define further respective portions of the path for air flow out of the sealed cavity during the vacuum draw process.

6. A refrigerator, comprising:

a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member, the first rib extending along an axis disposed at an angle of between 15° and 40° with respect to an edge of the first cover member comprising the perimeter portion;

a second cover member; and

a thermal bridge interconnecting the first cover member and the second cover member at the perimeter portions thereof to define an insulating cavity therebetween, wherein the insulating cavity is a sealed cavity having a vacuum drawn therefrom;

wherein the open interior portion of the first rib defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process.

7. The refrigerator of claim 6, wherein the first rib is one of a plurality of ribs comprising a first group of ribs extending in a first direction and a second group of ribs extending in a second direction oriented between 80° and 100° relative to the first direction, each of the plurality of ribs defining respective, interconnected open interior portions to further define respective additional portions of the path for air flow.

8. The refrigerator of claim 6, wherein the axis of the first rib is disposed at about 30° with respect to the edge.

9. The refrigerator of claim 6, wherein:

the first cover member is a side wall of an outer wrapper of the refrigerator;

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the second cover member is an inner liner disposed inward of the outer wrapper; and

the thermal bridge surrounds an opening to an inner cavity of the refrigerator defined by the inner liner, the refrigerator further including at least one door operably closing the opening.

10. The refrigerator of claim **6**, wherein:

the first cover member is a side wall of an outer wrapper of the refrigerator;

the second cover member is a unitary structural portion of the outer wrapper that defines a rear wall, a top wall, and a bottom wall of the outer wrapper, the second cover member being coupled to the first cover member along bottom, rear, and side edges of the perimeter portion; and

the thermal bridge interconnects the first cover member and the second cover member between a front edge of the first cover member and both a top-front edge and a bottom-front edge of the second cover member.

11. The refrigerator of claim **10**, wherein the second cover member defines a stepped area defined by a stepped segment of the second cover member within at least one of the rear wall and the top wall.

12. The refrigerator of claim **11**, wherein the stepped area defining a second portion of the path for air flow out of the sealed cavity, the vacuum insulating structure further including:

a mesh material layer received in the stepped area and configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area.

13. The refrigerator of claim **6**, further including an insulating material disposed within the insulating cavity, wherein:

the path for air flow out of the sealed cavity during the vacuum draw process facilitates removal of air from within the insulating material.

14. The refrigerator of claim **13**, wherein the first cover member further defines a stepped area including a stepped segment of the first cover member extending to the second planar level from the first planar level and defining a second portion of the path for air flow out of the sealed cavity, the vacuum insulating structure further including:

a mesh material layer received in the stepped area and configured to maintain the insulating material out of the portion of the air flow path defined within the stepped area.

15. The refrigerator of claim **14**, further including an air permeable member adhered between a portion of the mesh material layer and a portion of the inner surface of the first cover member.

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16. A refrigerator, comprising:

a first cover member of a stamped unitary sheet defining a perimeter portion positioned at a first planar level and a stepped area defined by a stepped segment of the first cover member disposed radially inward of the perimeter portion and extending to a second planar level from the first planar level, the first cover member being a unitary structural portion of an outer wrapper of the refrigerator that defines a rear wall, a top wall, and a bottom wall of the outer wrapper, the stepped area being a first stepped area, and the first cover member defining a second stepped area within the top wall of the unitary structural portion;

a second cover member defining a side wall of the outer wrapper of the refrigerator, the second cover member being coupled to the first cover member along bottom, rear, and side edges of the perimeter portion;

a thermal bridge interconnecting the first cover member and the second cover member between a front edge of the first cover member and both a top-front edge and a bottom-front edge of the second cover member to define an insulating cavity therebetween;

an insulating material disposed within the insulating cavity; and

a mesh material layer received in the stepped area;

wherein:

the insulating cavity is a sealed cavity having a vacuum drawn therefrom;

the stepped area defines a first portion of a path for air flow out of the sealed cavity during a vacuum draw process; and

the mesh material layer is configured to maintain the insulating material out of the first portion of the air flow path.

17. The refrigerator of claim **16**, further including an air permeable member adhered between a portion of the mesh material layer and a portion of an interior surface of the first cover member.

18. The refrigerator of claim **16**, wherein the stepped segment is a first stepped segment, the stepped area being further defined by a second stepped segment extending from the first planar level toward the second planar level, the second stepped segment being disposed radially inward of the first stepped segment.

19. The refrigerator of claim **16**, wherein the second cover member includes a first rib defining an open interior portion extending axially outward of an inner surface of the first cover member, the first rib extending along an axis disposed at an angle of between 15° and 40° with respect to an edge of the cover member comprising the perimeter portion and defining a second portion of the air flow path.

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